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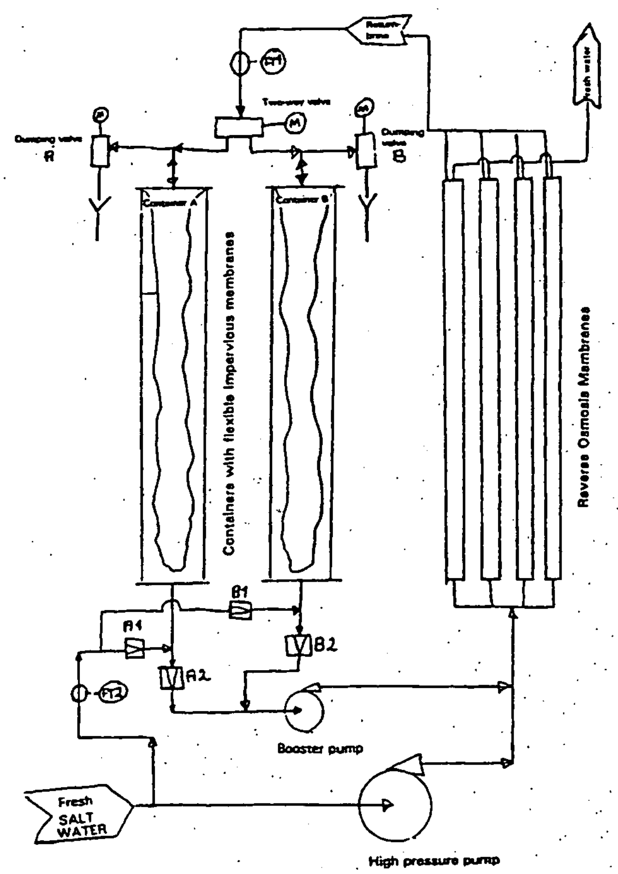
(54) Title: A METHOD AND A PLANT FOR PRODUCTION OF FRESH WATER FROM BRINY WATER



(57) Abstract: In connection with a reverse osmosis plant an energy recovery plant is arranged to utilize the pressure in the high pressure return-brine from the reverse osmosis plant. The energy recovery plant comprises two exchange containers operating in opposing phases, and for each container a return stage is implemented for the evacuation of return-brine, faster than the forward stage for the other container. This provides an uninterrupted flow to and from the reverse osmosis plant.

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A METHOD AND A PLANT FOR PRODUCTION OF FRESH WATER FROM BRINY WATER

This invention concerns the production of fresh water from briny water, normally seawater. The applied technology involves reverse osmosis whereby brine is supplied under high pressure with the assistance of a system supplying the high pressure to a container with a membrane, hereinafter called the Reverse Osmosis Membrane, that allows a certain proportion of the water to pass through as fresh water to the fresh water section that is kept at approximately atmospheric pressure. This type of technology is known per se, and is used particularly in parts of the world where access to seawater is plentiful, but where there is little fresh water. A problem with this technology is that it will normally involve a relatively high consumption of energy.

For the phenomenon of Reverse Osmosis to function satisfactorily it will be necessary to apply a relatively high pressure of salt water on the one side of the osmosis membrane, while the other side of the membrane is kept at approximately normal atmospheric pressure. The salt ions will then attempt to achieve a position of equilibrium over the membrane where, on the low pressure side there is water without salt, i.e. fresh water. In other words, the membrane will allow fresh water to pass through if a pressure is generated that is greater than the balance pressure (the so-called osmotic pressure, the force of which is dependent on the concentration of salt), and there is a drop in pressure due to the flow through the membrane.

Typical pressure used would be e.g. 65 bar on the high pressure side.

Plants that are in use and that can be purchased, produce pressure using, amongst other methods, multi-stage centrifugal pumps, propeller pumps or piston pumps. Brine is then led in to a Reverse Osmosis Membrane where typically 25-45% of the flow of water is separated off to fresh water. The remainder of the brine, subsequently called the return brine, typically 55-75%, is then released into the open air, and is thus subjected to a drop in pressure of approx. 65 bar, and in this connection large amounts of energy are lost.

There are systems for recovering some of this energy. The systems that are available today are mainly based on recovering energy in a hydro-turbine of either

the Pelton or the Francis type, and the recovered energy is transferred to the pump shaft or the motor shaft. The poor practical coefficients of performance achieved in turbines or in pumps have so far resulted in only moderate recovery of the energy that it is possible to recover.

Other systems for recovery are based on exchange containers/cylinders with pistons or flexible impermeable membranes where the return-brine drives the piston or the flexible impermeable membrane that again presses fresh salt water to the reverse osmosis membrane. Several systems that use this principle are described in other patent publications, cf. for example EP-A1-0,028,913, US 5,306,428, GB-A-2,030,056. As described, such systems mainly comprise two or more cylinders or containers, each cylinder or container having a salt-water side and a return-brine side, these being separated with the help of a piston or flexible impermeable membranes or sacks.

Each exchange cylinder or container has two operational modes, the one is such that the return-brine under pressure from the reverse osmosis filter presses fresh salt water to the return osmosis membrane. The necessary additional energy required to equalize the drop in pressure in the entire system and the energy required to press up a volume to the necessary pressure, equivalent to the produced fresh water, is supplied either directly to a possible piston in the cylinder or by one or more pumps, one of which can be a high pressure pump, and one of which can be a booster pump. When the cylinder or container is almost emptied of seawater and is thus filled by brine, a control system must govern one or more valves so that a new cylinder or container can commence pumping salt water. The cylinder or the container that is full of brine and that is practically emptied of fresh salt water, must then be pressure-balanced to open air by the control system and be refilled with fresh salt water. This is the second operational mode.

When successfully executed, such systems can recover a very high share of the pressure energy which can otherwise be lost, estimated at 85-98%. Up to the present time, such systems have not been successful and are today not available on the market. The reason for this is that no one has been able to make this process function without major variations and/or pressure hammer in the water volumes to/from the reverse osmosis membranes.

It is also necessary for the control system to know the position in the sequence, but at the present time and with existing technology there are no position indicators or other arrangements that can achieve this, and at the same time withstand the salt water and the variations in pressure required by the process.

This invention is conceived as a procedure and a plant to enable the method using pressure recovery with the help of cylinders/pistons or containers with flexible impermeable membranes to function without interruption or significant pressure hammer in the salt water flows to/from the reverse osmosis filters, thus making the method feasible for industrial utilization, thereby producing fresh water with the help of reverse osmosis with a lower consumption of energy than that which has been achievable so far. This can be accomplished with the help of the control system, a combination of the control system and valve types and a method for registering when the cylinder/container is empty. The procedure and the plant according to the invention are defined exactly in the appendixed patent claims.

With the help of a form of design of the invention, the use of pistons or flexible membranes can be avoided, thereby further increasing reliability. This is achieved by basing the separation between return-brine and fresh salt water on the control of a mixing zone for the two liquids, breaking off the sequence before the mixing zone leaves the containers and goes to the reverse osmosis membranes. Reference is otherwise made to the patent claims with regard to both this and other forms of design for the invention.

The invention will now be illustrated in more detail by looking at examples of design, and at the same time reference is made to the attached drawings in which

Fig. 1 shows an example of a turn-key facility according to the invention, using a design with membranes in exchange containers, and

Fig 2 shows a design of a valve with pressure equalization function.

According to the invention, a system is provided for the control of the pressure recovery process in fresh water production from reverse osmosis with the help of pressure recovery cylinders/exchange containers with pistons or containers with flexible/impermeable membranes. Such a control system can be used in a plant with for example two containers with membranes, see Fig. 1.

The high pressure pump pumps fresh seawater up to approx. 65 bar. This could be for example a multi-stage centrifugal pump, a propeller pump or a piston pump. This water then runs together with fresh salt water from the pressure recovery plant, also at the same pressure, e.g. approx. 65 bar, and this is then supplied to the reverse osmosis membranes. Here, e.g. 40% of the incoming salt water is separated out as fresh water, and in such a case, 60% of the water volume in will go out as return-brine with somewhat higher salt content in relation to the incoming fresh salt water. Pressure will typically be 1-4 bar lower than the input pressure, e.g. 62 bar. This water then goes to a two-way valve where the water is directed to the one container, e.g. container A. Here the impermeable flexible membrane will press fresh salt water out of container A to approximately the same pressure as the brine flowing into container A. Non-return valve A1 will prevent the water from being pressed back towards the supply of fresh salt water, and non-return valve A2 will allow the high pressure water to flow through. This now has a pressure of, for example, 61-62 bar and goes to a booster pump that pumps the water up to the pressure required to enable it to go into the reverse osmosis membranes.

The booster pump may also be placed in other positions in the cycle, e.g. after the outlet of brine from the reverse osmosis membranes. When container A is almost filled up with brine/emptied of fresh salt water, determined by the time T from start-up of filling of container A with brine, or following a signal from flowmeter FT1 that measures the volume of brine that has flowed into container A. The time T is determined on the basis of the volume to the container and the flow volume, so that container A is almost, but not completely, filled up with brine. If a flowmeter is used, this will give a signal when an equivalent volume is reached.

When the time T or the volume is reached, the control system sends a signal to the slide valve so that this changes over to supply brine to container B, and this will then be immediately pressurized and start to press fresh salt water out of the other end. According to the invention, this changeover shall take place in such a way that there is no interruption in the flow of brine/salt water from and to the reverse osmosis filter. This means that during changeover, the two-way valve must open to allow brine to enter container B at the same rate as it reduces the volume of brine to container A.

Container A is now practically full of brine/empty of fresh salt water, and when the two-way valve is fully changed over, dumping valve A will receive a signal from the control system to open, and container A will thereby be relieved of pressure down to atmospheric pressure. As a further improvement, small pressure relief valves and pressure build-up valves can be installed that open a certain time before the two-way valve or/and the dumping valve change over or open, i.e. 1-5 seconds in advance. Such pressure relief valves could typically have a cross-section of flow of 1-15 mm, and will carry out pressure relief/build-up of pressure in a moderate manner, thus avoiding the reactive force that can arise through the sudden changeover/opening of a large valve with a pressure differential of up to 65 bar.

As a further improvement the two-way and/or dumping valves can be designed in such a way that they have integral pressure-relief/build-up mechanisms so that the valves do not open/change over the main port before pressure equalization is almost completed. This can be achieved through the design of the valve so that the force exerted by the valve motor on the valve is not greater than that required to move the valve when pressure is practically equalized. The valve must thus be designed in such a way that pressures on both sides of the valve piston in combination with the surfaces subjected to pressure provide a net force on the valve piston that fulfils the aforementioned conditions. An example of such a valve is shown in Fig. 2.

The supply of fresh salt water which it is assumed can be supplied at the required low pressure of 0.5-5 bar, will thereby flow into container A on the other side of the impermeable flexible membrane through non-return valve A1. Non-return valve A2 will prevent the high pressure salt water that has now been pressed out of container B from flowing back to container A. The fresh salt water will thereby press brine out of container A via the flexible impermeable membrane and out through dumping valve A. According to the invention, it is decisive that the pressure in the fresh salt water is adjusted in such a way that it presses brine out faster in this container than the brine presses fresh salt water under high pressure out of the other container. This is because the system must have time to empty the brine in the one container (in this sequence stage container A), i.e. open dumping valve, empty the container of brine and shut the dumping valve before time T has

expired, or that the volume measured at FT1 has reached its predetermined value, so that container A is ready, full of fresh salt water when the two-way valve receives the signal to changeover to container A again.

It is also important to detect an endpoint for each filling/evacuating in order to prevent the sequence from driving at the start point, as this could cause the flexible impermeable membrane to empty the container of fresh salt water completely in the sequence stage where it supplies fresh salt water under pressure to the reverse osmosis membrane, resulting in interruption of the supply of water to the reverse osmosis membrane, and the risk of damaging the reverse osmosis membranes and the flexible impermeable membrane in the container.

According to the invention, such an endpoint can be detected by registering and measuring the volume of fresh seawater flowing into the container in the sequence stage where brine is dumped into the open air. When the container is completely empty of brine/full of fresh salt water, the impermeable flexible membrane will lie against the outlet arrangement, preventing more fresh salt water from flowing in. This will be registered by the flowmeter FT2 which will then transmit a signal to the control system instructing it to shut the dumping valve. This is conditional upon the outlet arrangement being made in such a way, and that the membrane is sufficiently sturdy to withstand this without being damaged. The pressure here is low, from 0.5 to 5 bar.

These principles, collectively or individually, for the control of such pressure recovery processes can be used in all processes that are based on the filling/evacuating of containers or cylinders.

As a further improvement, there can be an equivalent process in which the exchange containers or cylinders have neither membranes nor pistons separating brine and fresh salt water, but take as a basis that these liquids do not blend to a great extent. This can be achieved, among other things, with the help of an arrangement at each end of the cylinders/containers slowing down the inlet flow and distributing the liquid through e.g. a sieve plate covering the entire or large parts of the cross-section of the container. This is followed by interruption of the sequence stage where fresh salt water is pressed at high pressure to the reverse osmosis membranes, before the mixing zone reaches the outlet. This can be

decided on the basis of a time or by measuring conductivity, and one can continue to the next sequence stage when conductivity exceeds a predestined value.

Furthermore, that in the phase where the one container is pressure-balanced and where fresh salt water presses return-brine to the outlet, it is ensured that this is not interrupted before there is fresh salt water at the outlet. This endpoint can be decided on the basis of a predetermined time, or by measuring conductivity and the sequence stage is interrupted when conductivity drops below a predetermined value. By using upright containers with the return-brine at the bottom, the difference in density between return-brine and fresh seawater will minimalize the extent of the mixing zone.

PATENT CLAIMS

1. A method for the production of fresh water from briny water, particularly seawater, through the use of a reverse osmosis plant in which fresh salt water is fed into the reverse osmosis plant at the necessary high pressure by at least one high pressure pump in combination with an energy recovery plant that utilizes the pressure in the high pressure return-brine from the reverse osmosis plant to pressurize salt water in a sequential process with a forward sequential stage and a return stage, through two parallel exchange containers which will mainly be in opposing stages,
characterized in that the sequential process is controlled in such a way that the return stage is executed so much faster than the forward stage, so that the exchange container that is in the return stage, has time to exchange its content before the forward stage is completed for the other exchange container, whereby salt water is caused to flow uninterruptedly to the reverse osmosis plant, and return-brine uninterruptedly from the reverse osmosis plant.

2. The method according to claim 1, in that each exchange container contains a sliding separating piston or a flexible, impermeable membrane as a separator between return-brine and fresh salt water,
characterized in that the speed of the return stage is controlled by regulating the entry pressure of the fresh salt water, while return-brine is dumped to atmospheric pressure and fresh salt water is filled at the same time.

3. Method according to claims 1 or 2,
characterized in that separation of inflow of return-brine from the one container to the other is performed before the aforementioned one container is completely full of return-brine.

4. Method according to claim 3,
characterized in that changeover of inflow of return-brine from the one container to the other is controlled by the use of a predetermined time for return-

brine flow to the relevant container, this time being decided on the basis of the container's volume and the flow volume of the return-brine.

5. Method according to claim 3,
c h a r a c t e r i z e d i n that changeover of inflow of return-brine from the one container to the other is controlled on the basis of a metering signal from a flowmeter that measures the volume of return-brine flowing into the relevant container after the last changeover.

6. Method according to claims 1 or 2,
c h a r a c t e r i z e d i n that the end position for the return stage, i.e. when dumping return-brine to open air and filling fresh salt water in the relevant container, is decided by measuring the volume of fresh salt water to the container, and registering when this volume drops, thereby indicating that the container is full of fresh salt water and empty of return-brine.

7. Method according to claim 1, whereby an interface or a mixing zone is established between return-brine and fresh salt water in direct contact in the exchange containers,
c h a r a c t e r i z e d i n that control is based on controlling the position of the interface/mixing zone, its extent and movement, in that the forward sequency stage is completed before the interface/mixing zone reaches the outlet/inlet on the salt water side of the relevant container.

8. Method according to claim 7,
c h a r a c t e r i z e d i n that the inflow in each end of the containers is slowed down with the help of at least one sieve plate or screen to create a certain drop in pressure and to distribute the flow over the entire cross-section of the container.

9. Method according to claims 7 or 8,
c h a r a c t e r i z e d i n that the forward sequency stage is interrupted after a predetermined time in which quantity and container volume are included in the calculation and a good margin is given for the extent of the mixing zone, and that

the return stage is controlled in such a way that all return-brine and a certain proportion of fresh salt water is pressed to the outlet.

10. Method according to claims 7 or 8, characterized in that the sequency stages are controlled on the basis of signals from the conductivity meters in the containers for determining the movement of the interface/mixing zone past certain positions in the containers.

11. Method according to claim 1, characterized in that pressure equalization is undertaken by means of pressure increase and pressure reduction between sequency stages through the use of small actuator-controlled pressure relief and pressure build-up valves that open a certain time before the dumping or two-way valves change over to prevent hammering and vibration when the aforementioned large valves open or change over.

12. Method according to claim 1, characterized in that pressure equalization is undertaken by means of pressure increase and pressure reduction between sequency stages through the use of valves with integral pressure equalization mechanisms, arranged in such a way that the valve cannot change over or open before approximate pressure equalization is achieved.

13. A plant for production of fresh water from briny water, particularly seawater, comprising

- a reverse osmosis plant,
- at least one high pressure pump for the feeding in of fresh salt water to the reverse osmosis plant at the necessary high pressure,
- an energy recovery plant for utilization of pressure in the high pressure return-brine from the reverse osmosis plant for the pressurizing of fresh salt water on the input side of the reverse osmosis plant in combination with the high pressure pump,

- in which the energy recovery plant comprises two parallel exchange containers in which return-brine and fresh salt water meet in each of these, valves for distribution of return-brine to the containers and for the control of fresh salt water to and from the containers and for the control of return-brine for dumping, and a booster pump for providing high pressure for fresh salt water between the containers and the input side of the reverse osmosis plant, and
- in which the energy recovery plant works in a sequential process with a forward sequential stage and a return stage for the exchange containers, in that the two containers will mainly be at opposing stages,

characterized in that a control system for the process that is arranged so that the return stage is performed so much faster than the forward stage, allows the exchange container that is in the return stage to exchange its content before the forward stage for the other exchange container is completed, whereby salt water is caused to flow uninterruptedly to the reverse osmosis plant, and return-brine uninterruptedly from the reverse osmosis plant.

14. Plant according to claim 13,
characterized in that each exchange container contains a sliding separating piston or a flexible impervious membrane separating return-brine and fresh salt water, and that the control system is arranged to control the speed of the return stage by regulating the input pressure of the fresh salt water, bringing about dumping of return-brine to atmospheric pressure and at the same time filling with fresh salt water.

15. Plant according to claims 13 or 14,
characterized by at least one two-way valve for changeover of the return-brine flow to the containers, from one container to the other, this two-way valve having a sufficiently large available flow cross-section under the entire changeover so that interruption in, or major variation of flow volumes is avoided during the changeover.

16. Plant according to claims 13 or 14,
c h a r a c t e r i z e d b y at least one flowmeter for the metering of return-brine volume flowing into one container for the transmission of a signal to the control system.

17. Plant according to claims 13 or 14,
c h a r a c t e r i z e d b y at least one flowmeter for measurement of the volume of fresh salt water flowing into one container for transmission of a signal to the control system.

18. Plant according to claim 14,
c h a r a c t e r i z e d i n that the containers' outlet/inlet end on the return-brine side are designed in such a way that the pistons or membranes can withstand the difference in pressure between fresh salt water supplied in the return stage, and the return-brine's atmospheric pressure upon dumping when the container is completely emptied of return-brine and completely filled with fresh salt water.

19. Plant according to claim 13,
c h a r a c t e r i z e d i n that each exchange container is arranged to allow return-brine and fresh salt water to meet directly in an interface or mixing zone, and that the control system is arranged to control the position of the interface/mixing zone, the extent and movement in each container in that the forward sequency stage must be completed before the interface/mixing zone reaches the outlet/inlet on the salt water side of the relevant container.

20. Plant according to claim 19,
c h a r a c t e r i z e d b y at least one sieve plate or screen, placed at each end of the containers to create a certain drop in pressure and distribute the flow over the entire cross-section of the container.

21. Plant according to claim 19,
c h a r a c t e r i z e d b y conductivity meters placed in the containers for determining the movement of the interface/mixing zone past certain positions in the containers, and for the transmission of signals to the control system.

22. Plant according to claim 19,
c h a r a c t e r i z e d i n that exchange containers are arranged to stand upright, mainly vertically, and with the return-brine at the bottom.

23. Plant according to claim 13,
c h a r a c t e r i z e d b y small actuator-controlled pressure relief and pressure build-up valves placed in conjunction with dumping and two-way valves between the reverse osmosis plant and the return-brine side of the containers for pressure equalization and prevention of hammering and vibration upon changeover between sequence stages, and these small valves opening a certain time before the dumping or two-way valves change over.

24. Plant according to claim 13,
c h a r a c t e r i z e d i n that dumping and two-way valves between the reverse osmosis plant and the return-brine side of the containers have integral pressure equalization mechanisms arranged in such a way that the valve cannot change over or open before approximate pressure equalization is reached, whereby hammering and vibration can be avoided when increasing and reducing pressure in transitions between sequency stages.

Fig. 1

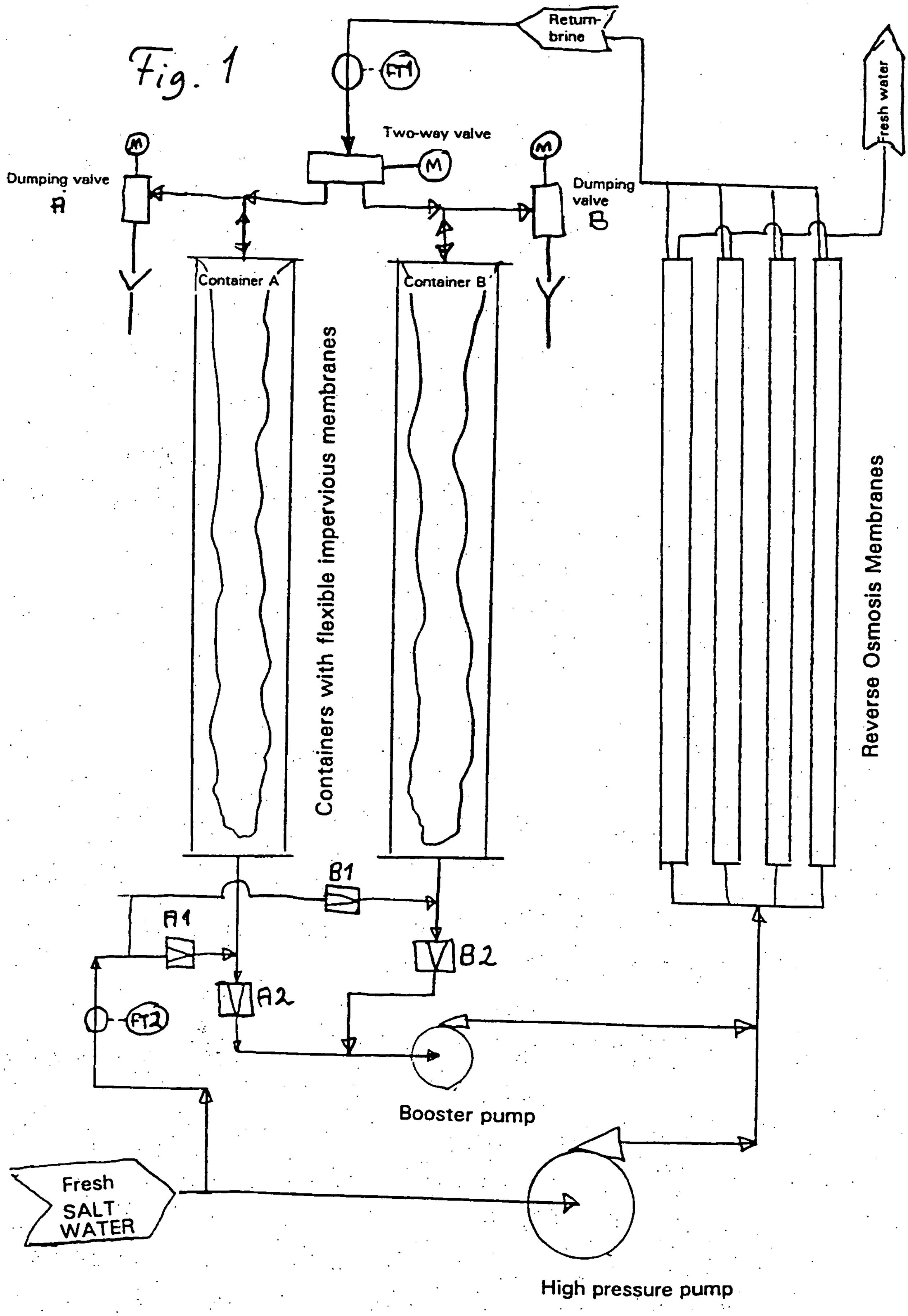
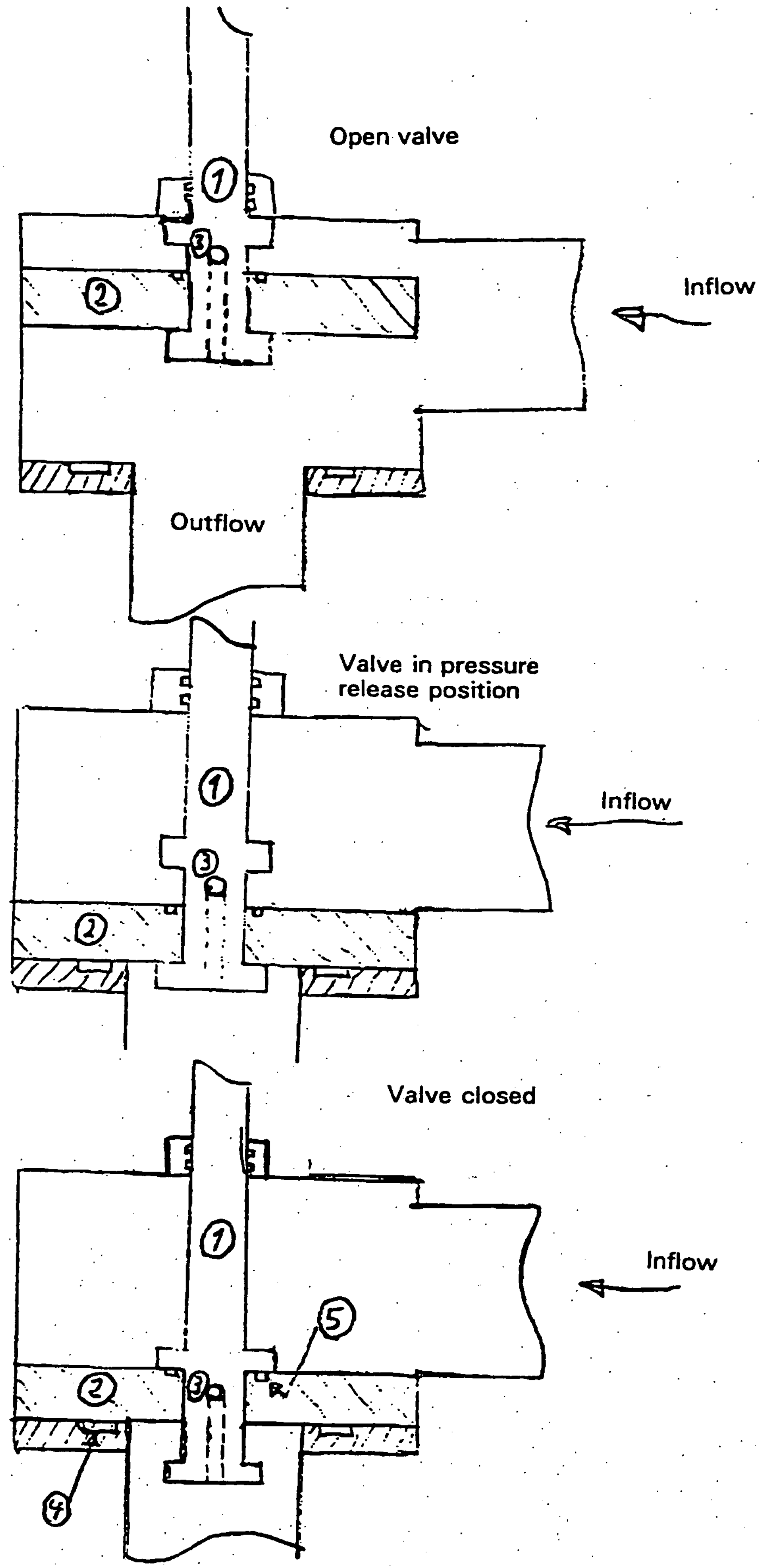

Return-brine
FT1
Fresh water
Two-way valve
M
Dumping valve
A
Dumping valve
B
Container A
Container B
Containers with flexible impervious membranes
Reverse Osmosis Membranes
B1
A1
B2
A2
FT2
Booster pump
Fresh SALT WATER
High pressure pump

Fig. 2



(1) Valve rod

(2) Valve piston

(3) Pressure relief opening

(4) Seal for valve piston

(5) Seal for valve rod

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 00/00210

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: B01D 61/02, C02F 1/44
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: B01D, C02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI,PAJ,EPODOC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5306428 A (JOHN B. TONNER), 26 April 1994 (26.04.94), column 2, line 16 - line 33; column 3, line 15 - line 25, figures 2-6, claims 1-4,9-10, abstract	1-6,13-18
A		7-12,19-24
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X	EP 0028913 A1 (SYKES OCEAN WATER LIMITED), 20 May 1981 (20.05.81), figure 1, claim 1, abstract	1,2,13
A		3-12,14-24
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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 Sept 2000	02 -10- 2000
Name and mailing address of the ISA/	Authorized officer

INTERNATIONAL SEARCH REPORT

International application No.
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4637783 A (GERRY B. ANDEEN), 20 January 1987 (20.01.87), column 1, line 60 - column 2, line 31, figures 1,2, abstract --	1-24
A	EP 0055981 A1 (RAMO MESPLE ET AL), 14 July 1982 (14.07.82), figures 1,3,4, claims 1-6, abstract -- --------	1-24

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/NO 00/00210

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